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ABSTRACTS FROM ASTRONOMICAL PUBLICATIONS.

In accordance with a recent arrangement the members of the scientific staff of the Lick Observatory hold meetings once per week, as an observatory duty, to report upon and discuss the more important articles appearing in the journals of astronomy, the important new books on astronomical subjects, or subjects of current and special interest in the observatory's work. It has been suggested that abstracts of the reports would be of interest to the readers of these Publications, and the Publication Committee has acted favorably upon the suggestion.

It is intended to preserve the qualities of abstracts as far as possible, and to restrict published criticisms, favorable or unfavorable, to a minimum.

ON THE MASSES OF SPECTROSCOPIC DOUBLE STARS.

In the Second Catalogue of Spectroscopic Binary Stars (Lick Observatory *Bulletin*, No. 181) I published the computed masses for the two components of ten O and B type binaries, of seven A type, of one F type, and of one G type. The masses for the O and B types are on the average six or seven times as great as the masses for the A, F and G types. I commented that "the O and B type systems appear to be the more massive, but the data are too meager to venture this as a conclusion."

In *Astronomische Nachrichten,* No. 4520, Professor LUDENDORFF of Potsdam has published an exceedingly interesting investigation on the average masses of spectroscopic double stars. As a basis he employed the orbits, as computed, for twenty-five spectroscopic double stars of classes Oe5 to B8, and for twenty-six spectroscopic double stars of classes A to K. For all such systems, whether we have observed both components or only one component, we can compute the values of $a \sin i$ and of

$$f = \frac{m_2^3 \sin^3 i}{(m_1 + m_2)^2} = [8.6013\text{–}10] \frac{(a \sin i)^3}{P^2},$$

in which $a \sin i$ is the projection of the semi-major axis of the orbit of the brighter component upon the line of sight, m_1 and m_2 are the masses of the principal and secondary components in each system respectively, i is the inclination of the orbit plane to the line of sight, P is the period of revolution in each system, and [8.6013–10] is a logarithmic constant. LUDENDORFF computed the values of $(a \sin i)^3$ for all the systems, and plotted these values in relation to the periods of revolution. He found that a simple curve would pass so nearly through the plotted points for the O and B type systems, and another similar curve for the A to K type systems, that these curves might be assumed as expressing the ideal relationship between $(a \sin i)^3$ and P. While the curves for the two spectral divisions are similar in form their scales are different. Discussing all available explanations for the difference in scale, LUDENDORFF was led to the conclusion that the combined masses of the twenty-five systems having O and B spectra must on the average be three times as great as the masses of the twenty-six systems having A to K spectra. He was led to construct therefrom a table which expresses the ideal masses of the components of spectroscopic binary systems for class B stars and for classes A to K stars, as functions of the ratios existing between the masses of the principal and secondary components in each system. For example: In a system having a principal component twice as massive as the secondary, the masses of the components are respectively 8 and 4 times the Sun's mass for a class B system, and 2.7 and 1.4 times the Sun's mass for a class A to K system; and, again, for a system whose components have equal masses, the masses of the individual components are respectively 1.8 and 1.8 times the Sun's mass for a class B system and 0.6 and 0.6 times the Sun's mass for a class A to K system.

In *Monthly Notices* of the Royal Astronomical Society for June, 1911, page 636, Dr. HALM, of the Cape of Good Hope Observatory, is led by a very brief discussion to a somewhat similar conclusion. Making use of the values of the relationship

$$f = \frac{m_2^3 \sin^3 i}{(m_1 + m_2)^2},$$

he concludes that the minimum combined mass of the two components in a class B system is on the average 16.3 times the Sun's mass, and in a class A to G system is on the average 1.9 times the Sun's mass; that is, the class B system is 8.6 times as massive as the A to G system.

It is necessary in appraising the values of these numerical results to remember that the spectroscopic binary systems thus far observed and investigated may not be strictly representative of their classes. Many of the systems included have been studied because they have long possessed special interest; the systems are in general the brightest of their classes, and they are in general those systems whose variable radial velocities have been most easily discoverable. The difference in the mass ratios obtained, 3 by LUDENDORFF and 8.6 by HALM, is perhaps indicative of the uncertainty which still exists on the subject.

Neither is it certain that the masses in spectroscopic systems are indicative of masses in single stars of the same spectral classes, for some doubt still exists as to the conditions which cause a rotating mass of gaseous matter to divide and form two stars in a system, or to remain as a single star.

W. W. CAMPBELL.

COMMUNITY OF MOTION AMONG SEVERAL STARS OF LARGE PROPER-MOTION.

Astronomical literature of the past seven years is full of references to KAPTEYN'S discovery that a preferential direction of motion exists amongst the stars. He showed in brief that while there are stars moving in all possible directions, there is to some extent a preference for motion toward a vertex situated near the point whose Right Ascension is 93° and Declination + 11°, and toward an anti-vertex occupying the antipodal point, as determined by several investigators.

In this connection Mr. BENJAMIN BOSS, of the Dudley Observatory, Albany, publishes an interesting article in *The Astronomical Journal*, No. 629. He calls attention first to an unpublished result, reached at the Dudley Observatory, to the effect that KAPTEYN'S preferential vertex is situated at Right Ascension 98°.4 and Declination + 9°.3. He states the further interesting facts: that the remarkable group of stars in *Taurus*, discovered by Professor LEWIS BOSS, is moving in a direction making an angle of about 15° with the axis of preferential motion pointing toward the vertex; that the *Ursa Major* group is moving along lines making angles of about 18° with the axis pointing toward the anti-vertex; and that recent unpublished researches made at the Dudley Observatory show that the class B stars have no apparent preference for motion toward the Kapteyn vertices.

These facts induced Mr. BENJAMIN BOSS to look for other streams of stars, having large motions, directed toward points near the vertex or anti-vertex. He found ten stars distributed, we might say, over the entire sphere, whose observed proper motions indicate that they are moving under high speed toward a convergent point at Right Ascension 99 ° and Declination 0 °. The stars are of the F, G and K types. Radial velocities are available for seven of these stars, and five out of the seven results appear to support Mr. Boss's conclusion.

The discussion of observational data is supplemented by a consideration of possible causes leading to the motion of groups of stars along lines essentially parallel, with speeds essentially equal. He suggests that the force which causes the preferential motion of the stars may be of an electro-magnetic nature. The lines of force in a magnetic field are curved, but imagining the poles to be far enough apart and the force of polarity relatively small, the curvature in any limited volume would be relatively slight. If a group of stars in a limited portion of the visible universe were to come under the influence of the electro-magnetic force, and that force alone, they would move along lines of force which are essentially parallel. Mr. Boss is of the opinion that the known increase of average velocities with advancing spectral type may have had its origin in the long-continued application of the electro-magnetic force referred to. The reviewer makes no attempt here to appraise the value of this hypothesis. W. W. CAMPBELL.

POSITION OF THE MOON DETERMINED PHOTOGRAPHICALLY.

In *Annals of Harvard College Observatory*, Vol. 72, No. 1, a brief historical note is given of the first attempt made to determine the Moon's position by photography, carried out by Professor G. P. BOND, on June 2, 1857. After a still briefer reference to other proposals and experiments to the same end, the paper is devoted to an account of a recent successful investigation undertaken at Harvard under Professor PICKERING'S direction, after consultation with Professor E. W. BROWN of Yale and Professor HENRY NORRIS RUSSELL of Princeton. The plates were measured and reduced by Professor RUSSELL, with the assistance of Professor A. H. JOY; the actual exposures were made by Mr. EDWARD S. KING of the Harvard College Observatory.

The practical difficulties of such an investigation lie in securing satisfactory images of the Moon and of the comparison stars on the same plate. "To secure comparable images," says Professor PICKERING, "the exposures to the Moon must be less than a thousandth of that of the stars. Moreover, the light of the Moon must be cut off from the object-glass of the telescope during the longer exposure, or the plate will be fogged by the light diffusely reflected by the glass." Finally, the clock work and mounting of the telescope must be of the highest excellence, as guiding in the usual way is impracticable, owing to the presence of the Moon in the center of the field.

Such a telescope was available at Harvard—the 16-inch Metcalf telescope. To secure proper exposures a pole was attached to it, projecting in front of the objective and carrying a disk of such size as to cut off the light from a circle equal to the diameter of the Moon plus its motion during the exposures. A cord was attached to the disk by which it could be turned edgewise for the short exposures to the Moon, and the disk was also connected electrically with a chronograph in such a manner that the circuit was broken when it was turned edgewise and closed when it again lay flat.

Thus, accurately timed exposures of $0^s.2$ to $0^s.4$ to the Moon and exposures to the stars of about 10 minutes were secured on the same plate. "The plates employed are of a fast emulsion and have the lines of a standard réseau photographed upon them."

In measuring the plates, settings were made on from ten to thirteen points on the limb of the Moon, usually at intersections of the limb and réseau lines, well distributed along the illuminated semi-circumference. From these positions the center of the Moon was determined. Settings were also made on from four to six comparison stars, and the right ascension and declination of the Moon's center thus determined.

Professor RUSSELL gives a careful discussion of the accuracy of the results of this investigation. His conclusions are:

"1. The probable errors of the photographic results are very little greater than was predicted from the known errors of observation. Hence no serious unknown errors appear to exist.

"2. The photographic method, at its first trial, gives results apparently somewhat superior in accuracy to meridian observations of the highest class."

Professor RUSSELL also points out that the method "possesses the two great advantages of independence, since its errors are for the most part different in nature and origin from those of meridian observations and of applicability over a wide range of hour angle."

R. G. AITKEN.

January, 1912.

RECENT PROGRESS IN SPECTROSCOPIC METHODS.

The address[1] of Professor A. A. MICHELSON, with the foregoing title, which was delivered at the Washington meeting of the American Association for the Advancement of Science, is one of unusual interest to the astronomer as well as to the physicist. It is to be regretted that the limitations of space prevent its publication as a whole. A succinct account is given of the various modern instruments for the analysis of light, the various methods are compared, and present and future progress is shown to rest almost wholly upon the securing of greater resolving power. The resolving power of the human eye is about 5,000,—that is, if an object presents a smaller angle than 1/5000, it is not "resolved." A one-inch telescope would have a resolving power of 100,000, while our mightiest telescopes would have a resolving power of about 2,000,000, powers which our best echelons or interference methods can scarcely equal.

"The parallelism of the problems which are attacked in astronomy and in spectroscopy is illustrated in the following table. It is interesting to observe how intimately these are connected and how their solution depends on almost exactly the same kind of improvement in the observing instruments, particularly on their resolving power; so that not only are the older problems facilitated and their solution correspondingly accurate, but new problems before thought to be utterly beyond reach are now the subject of daily investigation.

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[1] Published in *Science*, December 29, 1911.

	ASTRONOMICAL.	SPECTROSCOPIC.
1.	Discovery of new stars, nebulæ and comets.	Discovery of new elements.
2.	Star positions.	Wave-length of spectral lines.
3.	Double stars and star clusters.	Double lines, groups and bands.
4.	Shape and size of planets and nebulæ. ?Star discs.	Distribution of light in spectral "lines."
5.	Star motions (normal to line of sight). Resolution of doubles, solar vortices, protuberances, etc.	Star motions (parallel with the line of sight). Resolution of doubles, solar vortices, protuberances, etc.
6.		Changes of character and position of lines with temperature, pressure and magnetic field.
7.	Spectroheliograph. (Combination of telescope and spectroscope.)	

"We must especially note that the newer problems require an enormous resolving power. In the telescope this has been accomplished partly by the construction of giant refractors and partly by enormous reflectors; and, curiously enough, the same double path is open to spectroscopy; for we may employ the dispersive power of refracting media or the diffractive power of reflecting media. The increasing cost and difficulty of producing large transparent and homogeneous blocks of glass have tended to limit the size and efficiency of lenses and of prisms, and these have been more or less successfully replaced—the former by mirrors and the latter by diffraction gratings. . . .

"The diffraction grating possesses so many advantages in simplicity and convenience of manipulation that it is even now used in preference to these modern instruments, save for such refinements as require an exceptionally high resolving power. But has the resolving power of the grating been pushed to the limit? We have seen that this depends on the number of rulings; and it is certainly possible to increase this number.

But the theoretical value is only reached if the rulings are very accurately spaced; for instance, the resolving power of the Rowland grating is only one-third of its theoretical value. This is a direct consequence of inaccuracies in the spacing of the lines. If a grating could be constructed of say 250,000 lines with exact spacing, the resolving power would be equal to that of the most powerful echelon. The problem of the construction of such gratings has occupied my attention for some years; and while it has met with some formidable difficulties, it has had a fair measure of success and gives promise of still better results in the near future.

"The essential organ in all ruling engines in actual use is the screw which moves the optical surface to be ruled through equal places of the order of a five hundredth to one thousandth of a millimeter at each stroke; and the principal difficulty in the construction of the machine is to make the screw and its mounting so accurate that the errors are small compared with a thousandth of a millimeter.

"This is accomplished by a long and tedious process of grinding and testing which is the more difficult the longer the screw. A screw long enough to rule a two-inch grating could be prepared in a few weeks. ROWLAND's screw, which rules six-inch gratings, required two years or more—and a screw which is to rule a grating fifteen inches wide should be expected to take a much longer time, and, in fact, some ten years have been thus occupied.[1]

"I may be permitted to state a few of the difficulties encountered in this work—some of which would doubtless have been diminished if my predecessors in the field had been more communicative.

"First, is the exasperating slowness of the process of grinding and testing the screw. This can not be hurried, either by grinding at greater speed or by using any but the very finest grade of grinding material. The former would cause unequal expansions of the screw by heating, and the latter would soon wear down the threads till nothing would be left of the original form.

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[1] A method of ruling gratings accurately, which is independent of any mechanical device, is now in process of trial, in which the spacing is regulated by direct comparison with the light-waves from some homogeneous source such as the red radiations of cadimum.

"Secondly, in ruling a large grating, which may take eight to ten days, the ruling diamond (which must be selected and mounted with great care) has to trace a furrow several miles long in a surface as hard as steel—and often breaks down when the grating is half finished. The work cannot be continued with a new diamond and must be rejected and a new grating begun.

"Thirdly, the slightest yielding or lost motion in any of the parts—screw, nut, carriage or grating, or of the mechanism for moving the ruling diamond—is at once evidenced by a corresponding defect in the grating. When after weeks or sometimes months of preparation all seems in readiness to begin ruling, the diamond point gives way and as much time may have to be spent in trying out a new diamond.

"When the accumulation of difficulties has seemed insurmountable, a perfect grating is produced, the problem is considered solved, and the event celebrated with much rejoicing, only to find the next trial a failure. In fact, more time has been lost through such premature exhibitions of docility than in all the frank declarations of stubborn opposition!

"One comes to regard the machine as having a personality—I had almost said a feminine personality—requiring humoring, coaxing, cajoling—even threatening! But, finally, one realizes that the personality is that of an alert and skillful player in an intricate but fascinating game—who will take immediate advantage of the mistakes of his opponent, who 'springs' the most disconcerting surprises, who never leaves any result to chance —but who, nevertheless, plays fair—in strict accordance with the rules of the game. These rules he knows and makes no allowance if you do not. When you learn them and play accordingly, the game progresses as it should.

"As an illustration of the measure of success attained in this work I would call attention to a recent comparison by Messrs. GALE and LEMON of the performance of a grating of 6½-inch ruled surface with that of the echelon, the Perot and Fabry interferometer and the Lummer plate.

"The grating clearly separates six components, while the more recently devised instruments give from six to nine. Two of these components are at a distance apart of only one hundred and fiftieth of the distance between the sodium lines, and these are so widely separated by the grating that it would be possible to distinguish doublets of one-half to one-third this value; so that the actual resolving power is from 300,000 to 400,000—of the same order, therefore, as that of the echeleon.

"It may well be asked why it is necessary to go any further. The same question was put some twenty years ago when ROWLAND first astonished the scientific world with resolving powers of 100,000—and it was his belief that the width of the spectral lines themselves was so great that no further 'resolution' was possible. But it has been abundantly shown that this estimate proved in error, and we now know that there are problems whose solution depends on the use of resolving powers of at least a million, and others are in sight which will require ten million for their accurate solution, and it is safe to say that the supply will meet the demand.

"To return to our comparison of the telescope and the spectroscope; while the progress of investigation of the stellar universe will be ever furthered by increased size and resolving power of the telescope, this is very seriously hampered by the turbulence of the many miles of atmosphere through which the observations must be made. But there is no corresponding limit to the effective power of spectroscopes and the solution of the corresponding problems of the sub-atomic structures and motions of this ultra-microscopic universe may be confidently awaited in the near future.

"The message we receive from the depth of the stellar firmament or from the electric arcs of our laboratories, come they in a millionth of a second or in hundreds of light years, are faithful records of events of profound significance to the race. They come to us in cipher—in a language we are only beginning to understand.

"Our present duty is to make it possible to receive and to record such messages. When the time comes for a KEPLER and a NEWTON to translate them we may expect marvels which will require the utmost powers of our intellect to grasp."